Edited by
Dac-Nhuong Le
Chung Van Le
Jolanda G. Tromp
Gia Nhu Nguyen

New Technologies for Health and Medicine

Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0

Scrivener Publishing

WILEY

Emerging Technologies for Health and Medicine

Virtual Reality, Augmented Reality, Artificial Intelligence, Internet of Things, Robotics, Industry 4.0

Dac-Nhuong Le
Deputy-Head, Faculty of Information Technology, Haiphong University, Haiphong, Vietnam

Chung Van Le
CVS Center, Duy Tan University, Danang, Vietnam

Jolanda G. Tromp
University of New York in Oswego, NY, USA

Gia Nhu Nguyen
Dean, Graduate School, Duy Tan University, Danang, Vietnam

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Foreword

There are some key factors driving the increasing adoption of augmented reality (AR) and virtual reality (VR) technologies, which depend mainly on the growing integration of technology and digitization in the field of healthcare, as well as increasing healthcare expenditures which focus on delivery of efficient health services and its significance in training healthcare professionals. The advanced technologies related to AR and VR have a great effect on the healthcare industry with their adoption in virtual training of surgeons in 3D operating room simulations for difficult surgeries and as phobia buster in mental health treatment as well as for chronic pain management. Also, VR plays a major role in eye movement desensitization and reprocessing (EMDR) therapy to enable reframing of traumatic memories through certain eye movements. Furthermore, this technology offers benefits in various areas of care management such as autism and depression therapy, cancer therapy, and assisted living. VR-based organ models have played a crucial part in preparing surgeons for delicate and complicated operations that demand greater precision, less complications, and reduced trauma. On the other hand, AR is considered a useful active and powerful tool for training and education. AR-based applications are effectively used to provide the improved care of many patients. For example, the vein visualization technology, developed by AccuVein Inc. was developed to handle scanning, which helps doctors and nurses successfully locate veins and valves at the first go, reducing pain and the required time. These applications are also used in the aftercare of patients and assist elderly people in managing their medications. This book focuses on adopting robots in conjunction with VR and AR to help in healthcare and medicine applications; for instance, we discuss a training system developed for a lower limb rehabilitation robot based on virtual reality (VR), mainly including trajectory planning and VR control strategy. It can simulate bike riding and encourages patients to join in their recovery and rehabilitation through a built-in competitive game. The robot could achieve linear trajectory, circle trajectory and arbitrary trajectory based on speed control, in which the training velocity and acceleration in the trajectory planning have been simulated. A human-machine dynamics equation was built which is used to judge the intent of a patient's movement. The VR training mode is a variable speed active training under the constraint trajectory, and it has an adapting training posture function which can provide an individual riding training track according to the leg length of patients. The movement synchronization between the robot and virtual model was achieved by interaction control strategy, and the robot can change the training velocity based on the signal from feedback terrains in the game. A serious game

about a bike match in a forest was designed in which the user can select the training level as well as change perspective through the user interface.

The main purpose of this book is to publish the best papers submitted to the special session on VR/AR Healthcare and Medicine Applications at the International Conference on Communication, Management and Information Technology (ICCMIT 2018) in Madrid, Spain.[1] ICCMIT 2018 is an annual meeting for scientists, engineers and academicians to discuss the latest discoveries and realizations in the foundations, theory, models and applications of nature-inspired systems, and emerging areas related to the three tracks of the conference covering all aspects of communication, engineering, management, and information technology given by panels made up of world-class speakers and at workshops.

Prof. Ibrahiem El Emary
Prof. Musbah J. Aqel
International Cyprus University

[1] http://www.iccmit.net/

Preface

With the current advances in technology innovation, the field of medicine and healthcare is rapidly expanding and, as a result, many different areas of human health diagnostics, treatment and care are emerging. Wireless technology is getting faster and 5G mobile technology allows the Internet of Medical Things (IoMT) to greatly improve patient care and more effectively prevent illness from developing. This book provides an overview and review of the current and anticipated changes in medicine and healthcare due to new technologies and faster communication between users and devices. In Chapter 1, Abdullah *et al.* review the implications of VR and AR healthcare applications, and Chapter 5 provides a review of current augmenting dental care, by Nayyar and Nguyen. Chapter 6 provides an overview of typical human-computer interaction (HCI) informed empirical experiments and psychophysiological measurement tools that can help inform the development of user interface designs and novel ways to evaluate human behavior to responses in virtual reality (VR) and with VR and other new technologies by Munoz *et al.* In Chapter 12, Puri and Tromp provide provide a review of telemedicine technologies.

Patient Empowerment

Patient empowerment is facilitated by the wide availability of medical information via the internet and the ability to share reliable medical information, personal experiences with medicines and medical assessments via social media, in social groups established based on shared interests and a desire to support each other. This enables patients to have a voice in their healthcare procedures and exert more control and influence on healthcare worldwide, making it a very powerful technology-enabled medicine and healthcare improvement. This internationally accessible crowd sourced medicine and healthcare resource has the potential to change the role of patients from being passive witnesses in their own treatment to informed citizens proactively involved in monitoring and choosing treatments.

The e-NABLING Future project is a great example of patient empowerment. It is a global network of volunteers that share 3D printing designs and instructions to create prosthetic hands for free, thus enabling people in underdeveloped countries who have no access to prosthetics make their own at low cost. Medical 3D printing is still in its infancy; however, 3D bio-printers are already commercially available, making the printing of human body parts from bio-ink containing real human cells a commonplace occurrence in the near future.

Chapter 3 describes various technologies that enable patient empowerment and build empathy in young children using AR, as shown in a case study in Malaysia by Zamin *et al.* In Chapter 4, Garcia *et al.* report on the empirical experiments used to test the effectiveness of VR for mock interview training. In Chapter 7, AI technologies for mobile stroke monitoring and rehabilitation robotics control are discussed by Elbagoury *et al.* In Chapter 9, Elbagoury *et al.* discuss an AI-powered "doctor brain" app, along with artificial intelligence (AI) for healthcare based on the Internet of Things (IoT). In Chapter 10, an artificial intelligence mobile cloud computing tool is discussed by Shalhoub *et al.*, and the previously mentioned Chapters 1 and 3 also include discussions on patient empowerment through new technologies for medicine and healthcare.

Smart Wearable Sensors

Smart wearable home sensor technologies contribute to the empowerment of patients. These technologies, such as the popular Fitbit, give users more insight and control over their health and can help prevent illness by giving real-time feedback on health status by monitoring vital signs, allowing the user to adjust and target their activities to reach optimal fitness or health results. In Chapter 14, Kolhe *et al.* discuss smart wearable sensors, along with automation of appliances using electroencephalography. In Chapter 18, Kolhe *et al.* discuss smart home personal assistants and baby monitoring systems, previously mentioned in Chapters 1, 3, 6, 8 and 15.

Real-time health feedback is extremely suitable for gamification, as behavioral change and motivation regarding exercise can be influenced by adding points and badges and leader-boards to the data stored in the cloud and on the device. These wearable sensors are becoming smaller, less obtrusive and more integrated with the human body. For instance, Google's digital contact lens will allow diabetes patients to monitor and manage their glucose levels from tears in real time.

Additional integration can be expected from digestible sensors, sensors placed in teeth and organs of the body and thin e-skin sensors or biometric tattoos and radio frequency identification chips (RFID) implanted under the skin, which store vital health information and act as control devices for purposes such as automatically calling for assistance if vital signs signify that health problems are imminent. Early adopters of these new technologies are already using implants to give themselves superpowers; for instance, the use of recreational cyborgs to improve their eyesight or hearing.

Medicine and Healthcare Education

Another area that will benefit greatly from technological advances is medicine and healthcare education. Medical students can now learn anatomy and practice operations in virtual reality, allowing them to interact with the human models in real

time and zoom in and out to focus on the details, in a way that has not been possible before. In Chapter 2, Le *et al.* discuss the use of 3D simulation in medical education, in which VR is used in extensive user (*students and teachers*) acceptance comparative testing for teaching anatomy. Additionally, augmented reality can help to provide real time instructions and visualizations, as discussed in the previously mentioned Chapter 5, such as the Microsoft Hololens app for use in the OR, showing where the blood veins are located in a body part. With the use of 360 degree video cameras, anyone can observe operations in progress in real time.

Artificial Intelligence

Artificial intelligence (AI) will be able to assist doctors in medical decision making. The IBM Watson computer system has already shown great potential in helping to analyze symptoms and prescribe the best treatment (for more details see https://www.ibm.com/watson/). Watson can read 40 million documents in 15 seconds and suggests treatments based on the analysis. Watson will not replace human doctors because it does not answer medical questions, instead it analyzes medical information and comes up with the most relevant potential outcomes that can help them make the most informed decisions in the shortest amount of time. In Chapter 8, Shalhoub *et al.* address the topic of artificial intelligence for smart cancer diagnosis. and in Chapter 10 Shalhoub *et al.* discuss an artificial intelligence mobile-cloud computing tool. Ionel-Alexandru *et al.* discuss advanced intelligent robot control interfaces for VR simulation in Chapter 11, and along with the previously mentioned Chapter 8 AI topics relevant for innovation of medicine and healthcare technologies.

Google's DeepMind Health mines data from medical records with the aim of improving health services by making them faster, more accurate and more efficient. It has the potential to be bigger than the Human Genome Project. Google is also working on the ultimate artificial intelligence-controlled brain under the supervision of Ray Kurzweil, director of engineering at Google. He predicts that the singularity (*the moment when artificial intelligence exceeds man's intellectual capacity*) will only take about 10 years of further development. It will allow us to connect our neocortex to the internet and develop our creativity.

Artificial intelligence also drives medical robot assistants that will be of great use in care homes and hospitals and even for home care. Robots can be made to lift more weight than humans and have already been developed to assist in carrying medical equipment and patients, helping patients get out of bed into their wheelchairs, etc. More complex robots equipped with image analysis techniques are under development to help with more complex tasks. In Chapter 13, Migdalovici *et al.* discuss an environment model applied on the critical position of the walking robots. and in Chapter 14, Pop *et al.* discuss walking robot equilibrium recovery applied on the NAO robot. In Chapter 15, Zamin *et al.* discuss the development of a robotic teaching aid for disabled children in Malaysia; and the previously mentioned Chapters 1, 3, 6 and 10 discuss various applications of robotics in medicine and healthcare innovation.

Real-Time Diagnostics

Real-time diagnostics tools will provide technological advances and new application areas, and help reduce the complexity of medical procedures and analysis, such as, for instance, the iKnife, an intelligent surgical knife that can identify malignant tissue to remove as the operation is in progress.

Other New Technologies in the Technology Innovation fields for Medicine and Healthcare

In order to complete the overview of current predictions, we discuss a few more new technologies that are expected to revolutionize the medicine and healthcare industries and services. The technology advancements discussed here are in-silico organs-on-chips technology, optogenetics and multifunctional radiology. Finally, we discuss some of the perceived risks and dangers that need to be considered before adopting some of these new technologies into our medicine and healthcare treatments.

A huge advance in clinical trials is predicted from the in-silico organs-on-chips technology. Microchips simulate cells and whole human organs and systems, so that drugs can be tested without risk to human or animal subjects, making clinical trials more efficient and accurate. The Human Genome Project which mapped all the human genes, generating the field of genomics, makes it possible to use DNA analysis to customize health procedures and medicines. The Personalized Medicine Coalition aims to help bring about the paradigm shift to personalized healthcare (see their latest report[1]).

Optogenetics is a promising new technique used in neuroscience. It uses genes of proteins that are sensitive to light. These are then used to precisely monitor and control their activity by using light signals after introducing them in specific brain cells. This allows researchers to control how nerve cells communicate in real time, with completely wireless techniques so that complex behaviors can be observed while the experimental subjects can freely move around. This technology will be very helpful in understanding the neural codes for psychiatric and neurological disorders.

Multifunctional radiology is developing very fast and within the next 10 years great progress can be expected from this technology advancement. Radiology uses medical imaging to diagnose and sometimes also treat diseases within the body. Multifunctional radiology consists of one machine that can detect many different medical problems at once. This will make practitioners more productive and one machine will take up less space than multiple devices, making the workspace more efficient.

The most profound risks regarding the adoption of the Internet of Medical Things (IoMT) are the finances and ability to adapt to the changing healthcare and medicine industry itself, in addition to all the other institutions that need to adopt

[1] http://www.personalizedmedicinecoalition.org /Userfiles/PMC-Corporate/file/The PM Report.pdf

these new technologies. This also includes the finances for the implementation of new regulations. As new technologies are used for medicine and healthcare, governments will have to keep up with the change, by providing the best regulations for these new services to the public. This requires significant resources from multiple regulatory bodies and governments.

Another problem is caused by the diversity in medical record keeping technologies, and the lack of compatibility and interoperability between the different systems used by institutions. If data cannot be shared efficiently, it cannot be merged and aggregated for improvement of information exchange and patient record sharing between the different medical experts the patient may have to deal with. This can significantly slow down the progress of big data analysis and communications between institutions with different or incompatible database designs.

Major demographic shifts are taking place in the populations around the world. Populations are growing and aging and the number of patient cases are rising as a result, which drives the costs of healthcare up. If current trends persist there will be nearly 1.5 billion people ages 65 or older by 2050 and they will significantly outnumber children younger than 5. It is projected that more than 60% of the Baby Boomer generation will be managing more than one chronic condition by 2030. Our medicine and healthcare systems need to help these patients by managing the increased cost of healthcare, as they are expected to make twice as many visits to physicians and hospitals by 2030. With improved healthcare, life expectancy is increasing, and while the prevalence of severe disabilities can be expected to decrease along with this improvement, milder chronic diseases and the need for solutions, such as remote disease management, engagement and patient responsibility for monitoring their own symptoms and treatments, will increase.

Dr. Jolanda G. Tromp
University of New York in Oswego
New York, USA